PATAPSCO SHAD AND HERRING RESTORATION

2014 Monitoring Progress Report

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Under the Supervision of

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Introduction

The Masonville Dredged Material Containment Facility (DMCF) was designed to accommodate Baltimore Harbor dredged material, which is statutorily required to be placed in a confined disposal facility. As a component of the DMCF project, the Maryland Department of Transportation Port Administration (MPA) was required to develop a compensatory mitigation package to offset impacts associated with filling approximately 130 acres (53 hectares) of open water in the Patapsco River; a major tributary to the Chesapeake Bay. The mitigation projects focused , in part, on onsite and in-kind restoration of the adjacent Masonville Cove, including shoreline stabilization and erosion control, reef creation and substrate improvement, and creation and enhancement of tidal and non-tidal wetlands. Mitigation also incorporated offsite and out-of–kind mitigation projects. Under this mitigation category, Patapsco River shad and herring restoration was selected, and is the subject of this monitoring report.

The MPA has funded the Maryland Department of Natural Resources (DNR) to lead the Patapsco River shad and herring restoration effort. DNR contracted the U.S. Fish & Wildlife Service, Maryland Fishery Resources Office (MFRO) to perform monitoring activities of stocking efforts including field sampling and collections, laboratory sample preparation and interpretation, data analysis, and report writing. This report represents year two (Project year 3) of a five-year monitoring effort.

Need (From the project Scope of Work)

American Shad (*Alosa sapidissima*) was once the most important commercial and recreational fish species in the Chesapeake Bay. In response to severe population declines from 1900 to the 1970's, Maryland closed its fishery in 1980. Various factors that contributed to the decline include over-fishing, stream blockages, and poor water quality (Hildebrand and Schroeder 1928). Severely depressed or extirpated native adult stocks do not presently utilize most Chesapeake Bay tributaries, including the Patapsco River (Klauda et al., 1991). This tributary has historically supported spawning stocks. Improvements in water quality, sustained fishing moratorium, and planned removal of many stream blockages has reopened potential shad spawning habitat. Since shad show evidence of density dependent spawning behavior, self-sustaining shad populations are not likely to return to tributaries without hatchery inputs (Marcy 1976). Development of spawning, culture, marking, and stocking techniques could reintroduce and enhance spawning populations of American Shad to this target tributary. Funding obtained through Sport Fish Restoration Act F-57-R has supported a DNR shad restoration program since 1999 in other Maryland tributaries to the Chesapeake Bay. Substantial progress was previously documented in the Patuxent and Choptank rivers. Techniques and strategies developed in that program have been applied to Patapsco River restoration efforts.

Hickory Shad (*Alosa mediocris*) were historically abundant in many Chesapeake Bay tributaries. Recently, some upper Bay tributaries have experienced a mild resurgence in Hickory Shad runs. The availability of Hickory Shad brood stock provides the opportunity to culture and stock this species. Few studies have been conducted on Hickory Shad and little is known about their life history in Chesapeake Bay. Previous work conducted under F-57-R funding has yielded new Hickory Shad spawning strategy and life history information (Richardson et al., 2007). Many Bay tributaries had historical Hickory Shad runs equal to or greater than that of American Shad, and it could be useful to develop natural spawn, culture, and marking techniques for their restoration. These techniques have been refined during ongoing restoration projects, and have been applied to the Patapsco River.

River herring is the collective term for the Clupeidae Alewife (*Alosa pseudoharengus*) and Blueback Herring (*Alosa aestivalis*). These species have experienced recent declines coast-wide and throughout the Chesapeake Region. Dams have blocked much of the Patapsco River herring spawning habitat for decades. Recent and planned dam removal will reopen historical spawning habitat, and reintroduction and enhancement through hatchery inputs could have positive, local population impacts.

Maryland DNR restoration work thus far indicates that self-sustaining shad restoration will likely occur over a period of decades, rather than years. The Patuxent River has been stocked at a high level since 1994, and it has only been during the last several years that wild juvenile abundance has been increasing. Herring restoration would likely occur in a shorter time frame due to their younger age at maturity. The long time frame for American Shad restoration limits potential adult assessment activities considering the five-year monitoring funding commitment from the Masonville project. However, stocking larvae and juveniles for a period of three years at a high level should result in the presence of Patapsco River spawning adults in five to six years. Hickory Shad adults should return to the Patapsco River primarily at age three. Limited assessment of Hickory Shad adults will be conducted beginning in the third year of project monitoring, although some Hickory Shad adults could return at age two. Results for herring stocking should appear more quickly in adult sampling, and some indication of success could be apparent within the sampling timeframe. Larval and juvenile sampling for all target species will provide information on the current populations, and the impacts of stocking hatchery-cultured fish.

Objective

The overall objective of the Patapsco Shad and Herring Restoration Project is to introduce larval and juvenile American Shad, Hickory Shad, Alewife, and Blueback Herring populations to the river, and in so doing produce adult stock of hatchery-origin fish that will return to spawn. The objective of the monitoring component is to determine the extent to which the overall objective has been met by assessing the contribution of hatchery fish to the adult spawning population and, in comparison, monitoring recovery of naturally produced stocks.

Overall Project Expected Results and Benefits

Hatchery inputs are intended to provide adult spawning stock that could produce self-sustaining populations in the target tributary. These hatchery fish have tremendous value for stock assessment purposes at the larval, juvenile, and adult life stages since all stocked fish receive an oxytetracycline otolith mark. Natural spawn and strip spawn culture techniques allow for the production of large numbers of larval and juvenile shad and herring for stocking and assessment efforts.

Upper Bay shad populations currently support popular catch and release recreational fishing. Restoring shad and herring stocks to other tributaries that historically supported runs will increase fishing opportunities for anglers. Recreational fishing that targets Hickory Shad and American Shad is occurring in the Patuxent and Choptank rivers, primarily due to ongoing restoration efforts.

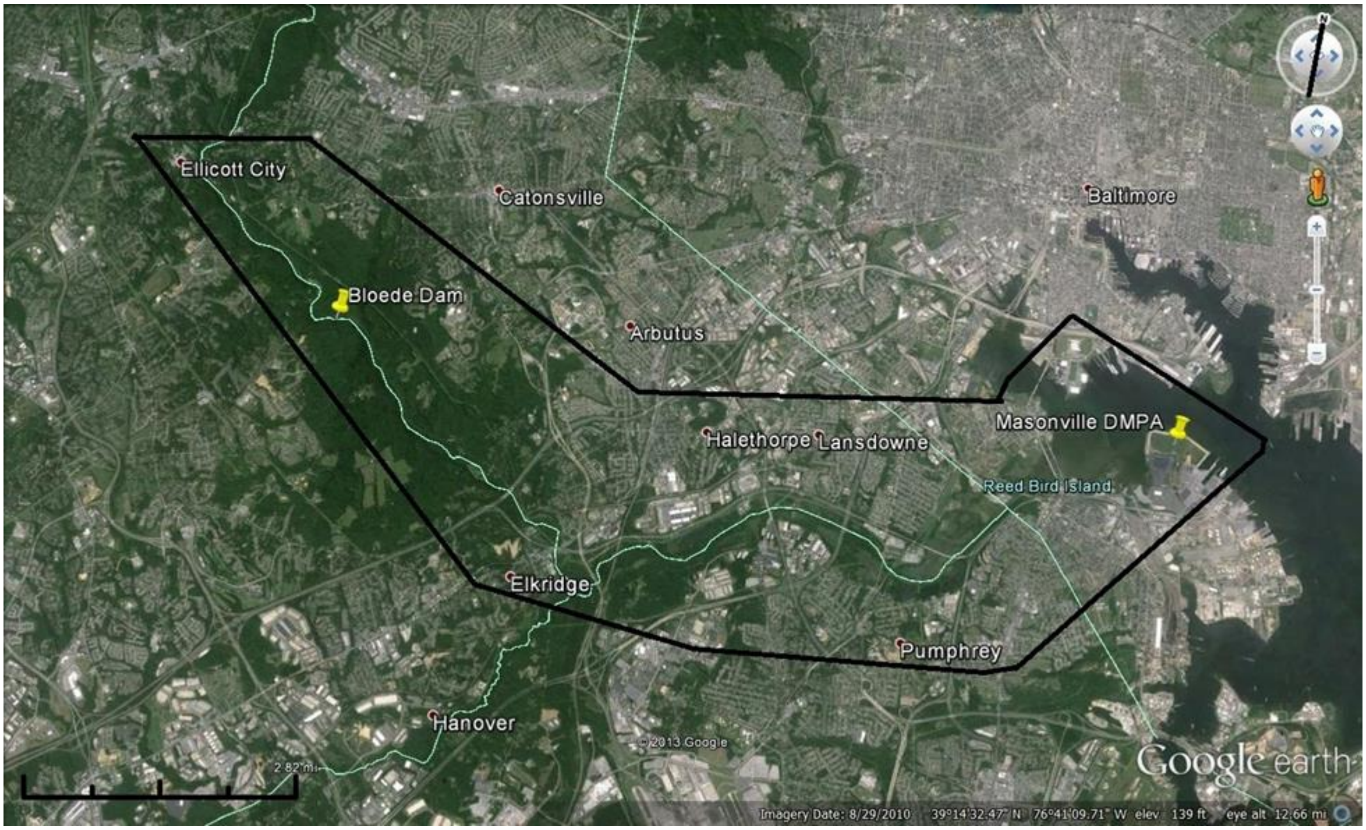
The Patapsco River watershed is heavily impacted by urban, commercial, and industrial development but has been the subject of numerous mitigation efforts due to its designation as a targeted watershed (i.e. sewage treatment upgrades and dam removals). If successful, this restoration effort should improve recreational fishing opportunities in the river. Figure 1 depicts the targeted watershed and river sections sampled.

Approach

The project consists of three sub-projects:

1. *Produce, mark, and stock cultured American Shad, Hickory Shad , and herring in the Patapsco River (Project years 1-4).*
2. *Monitor the abundance and mortality rates of larval and juvenile shad and herring using marked hatchery-produced fish (Project years 2-6).*
3. *Assess the contribution of hatchery fish to the adult Hickory Shad and herring spawning population (Project years 2-6).*

Figure 1. *2014 Patapsco River monitoring target area.*



Sub-project 1:
Produce, mark, and stock cultured American Shad, Hickory Shad, and herring in the Patapsco River.

Sub-Project 1 activities were conducted by the DNR, and are described in detail in the overall project report. The following briefly summarizes select sections of that report.

Under Sub-project 1, DNR developed stocking goals based on past experience with shad restoration.

Table 1**.** *2014 Maryland DNR shad and herring stocking goals for the Patapsco River. Early juveniles are stocked at approximately 30-d age.*

Species	Stocking Phase	Stocking Goal
American Shad	Larvae	200,000
American Shad	Early Juvenile	75,000
Hickory Shad	Larvae	500,000
Hickory Shad	Early Juvenile	75,000
Alewife	Larvae	500,000
Blueback Herring	Larvae	500,000

Stocking

Manning State Fish Hatchery (Brandywine, Maryland) produced the larval and early juvenile fish stocked into the Patapsco River beginning in project year two. Project year one involved upgrades to the hatchery including pond construction and well installation. Stocking was accomplished outside the boundaries of Patapsco Valley State Park, which covers 32 linear miles (20 kilometers) of the Patapsco River, and encompasses 16,943 acres (6,492 hectares) in Howard and Baltimore Counties, Maryland. Stocking was performed in tidal portions of the Patapsco River, with larval stocking occurring where Route 648 crosses the river, and early juvenile stocking occurring at SW Area Park (Figure 2). Stocking began in early April 2014, and continued through early June 2014 (Table 2). All stocked fish received an oxytetracycline (OTC) Mark. Table 2 shows the day age of OTC larval immersion.

Figure 2. *Locations of Patapsco River stocking of larval (Route 648 Bridge) and early juveniles(SW Area Park) for 2014. Note different locations stocking sites of larval (red dot) and early juveniles (green dot) from 2013.*

Table 2. *Maryland DNR Patapsco River shad and herring stocking events in 2014. Species number stocked totaled: 795,000 Alewife, 160,000 American Shad, 679,500 Blueback Herring, and 538,500 Hickory Shad.*

Date	Species	Life Stage	Mark	# Stocked
4/06/2014	Alewife	Larvae	Day 1	80,000
4/07/2014	Alewife	Larvae	Day 1	150,000
4/12/2014	Alewife	Larvae	Day 1	400,000
4/17/2014	Alewife	Larvae	Day 1	70,000
5/21/2014	Alewife	Early Juvenile	Day 1,3	65,000
5/22/2014	Alewife	Early Juvenile	Day 1,3	30,000
5/22/2014	American Shad	Larvae	Day 3	90,000
6/03/2014	American Shad	Early Juvenile	Day 3,6	70,000
5/10/2014	Blueback Herring	Larvae	Day 1	185,000
5/13/2014	Blueback Herring	Larvae	Day 1	90,000
5/19/2014	Blueback Herring	Larvae	Day 1	200,000
5/21/2014	Blueback Herring	Larvae	Day 1	350,000
6/05/2014	Blueback Herring	Early Juvenile	Day 1,3	1,500
4/23/2014	Hickory Shad	Larvae	Day 1	185,000
4/25/2014	Hickory Shad	Larvae	Day 1	150,000
5/04/2014	Hickory Shad	Larvae	Day 1	20,000
5/04/2014	Hickory Shad	Larvae	Day 1	110,000
6/02/2014	Hickory Shad	Early Juvenile	Day 1,3	55,000
6/05/2014	Hickory Shad	Early Juvenile	Day 1,3	5,000
6/09/2014	Hickory Shad	Early Juvenile	Day 1,3	13,500

Sub-project 2:
Monitor the abundance and mortality of Patapsco River larval and juvenile shad and herring using marked hatchery-produced fish.

Materials and Methods

Sampling surveys were conducted to assess the larval and juvenile shad and herring populations in the Patapsco River. Two survey types attempted to capture early life stage shad and herring:

1. Larval ichthyoplankton drift or tow net survey.
2. Juvenile seine survey.

FIELD SAMPLING (LARVAL ICHTHYOPLANKTON NET)

Ichthyoplankton sampling began April 4, 2014 and continued through May 29, 2014. Maryland Biological Stream Survey (MBSS) participated with this portion of the study by conducting early life stage sampling using drift nets at two upper Patapsco River locations, upstream from the Route I 95 crossing of the river (Figure 3). On the lower section of the river, MFRO sampled two reaches downriver of the light rail crossing of the Patapsco using an ichthyoplankton tow net (Figure 4). Using both types of gear, sampling occurred once a week.

Drift nets were constructed of 360 micron mesh material, sewn into a cone 157 cm long attached to a square frame with a 300 x 460 mm opening. The stream drift net configuration and techniques were the same as those used by O'Dell et al. (1975). The frame was connected to a handle so that the net could be held stationary in the stream. Nets had a threaded collar on the end which allowed the connection of a Mason jar for sample collection. Nets were placed in the stream for five minutes with the opening facing upstream.

Due to low flows in the lower section of the river, tow nets were selected to augment the volume of water being sampled. Tow nets were constructed of the same mesh material and had the same dimensions, however the opening was a circular frame, with a diameter of 500 mm. Fauna collection via an attached Mason jar was the same. The net was fitted at the mouth with a flow gage (G.O. Environmental) in order to have the ability to calculate volume of water sampled. Additionally, a bullet float was attached above the mouth frame to keep the net off the river bottom. Nets were deployed off the stern of the boat and towed at a slow speed (< 6 knots) for five minutes at two different river reaches.

Upon retrieval, both types of nets were rinsed in the stream/river by repeatedly dipping the lower part of the net (cod end) and splashing water through the outside of the net to avoid sample contamination. The jar was then removed from the net and an identification label affixed describing site, date, time, and collectors. Another label with the same information was placed in the jar. Either during sampling, or at the end of the sampling day, all samples were preserved with 10% buffered formalin. Samples not preserved immediately were placed in a cooler. Prior to sealing each jar for transport, approximately 2 ml of Rose Bengal dye was added to each jar in order to stain any organism red to aid future sorting. Water temperature (^{o}C), conductivity

Figure 3. *2013 MBSS Patapsco River shad and herring larval ichthyoplankton sampling locations.*

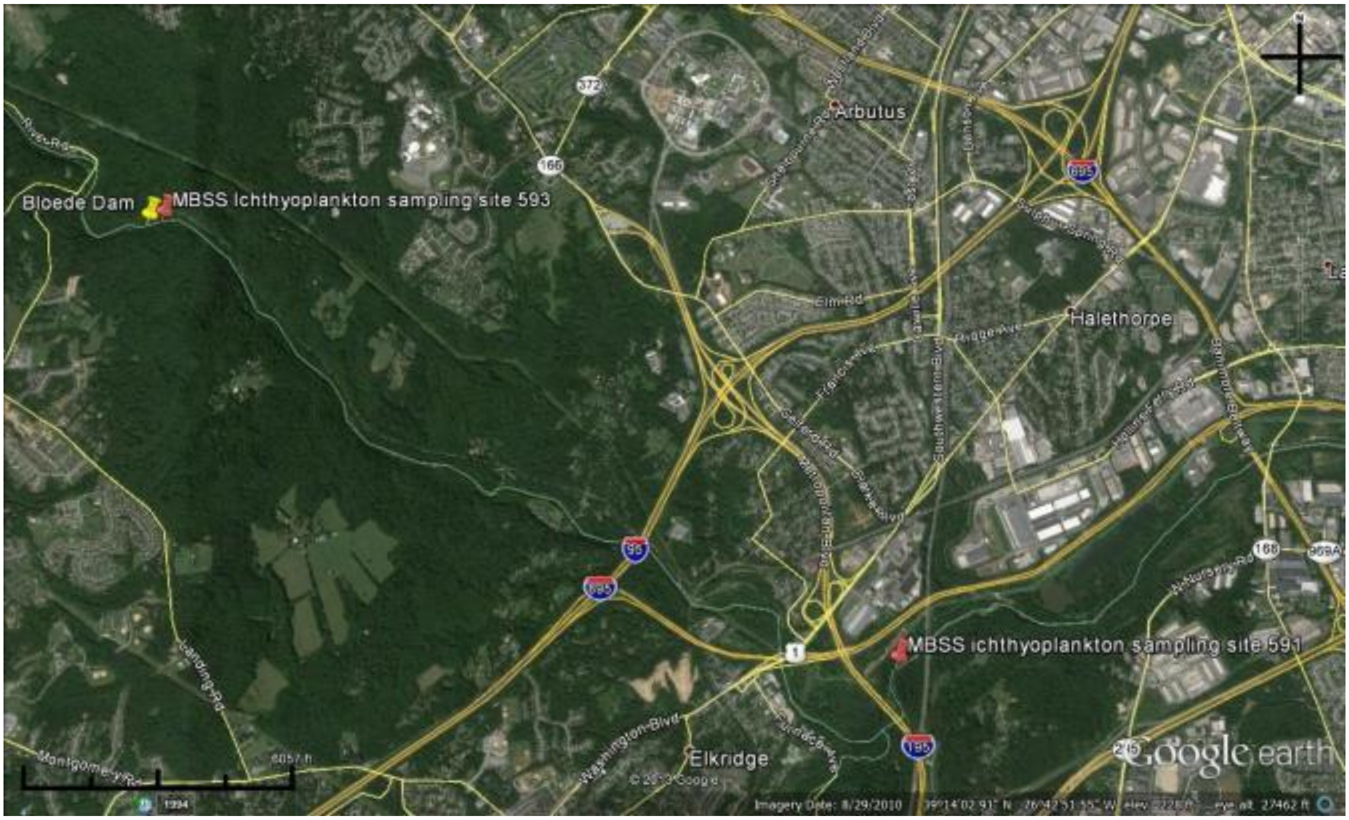
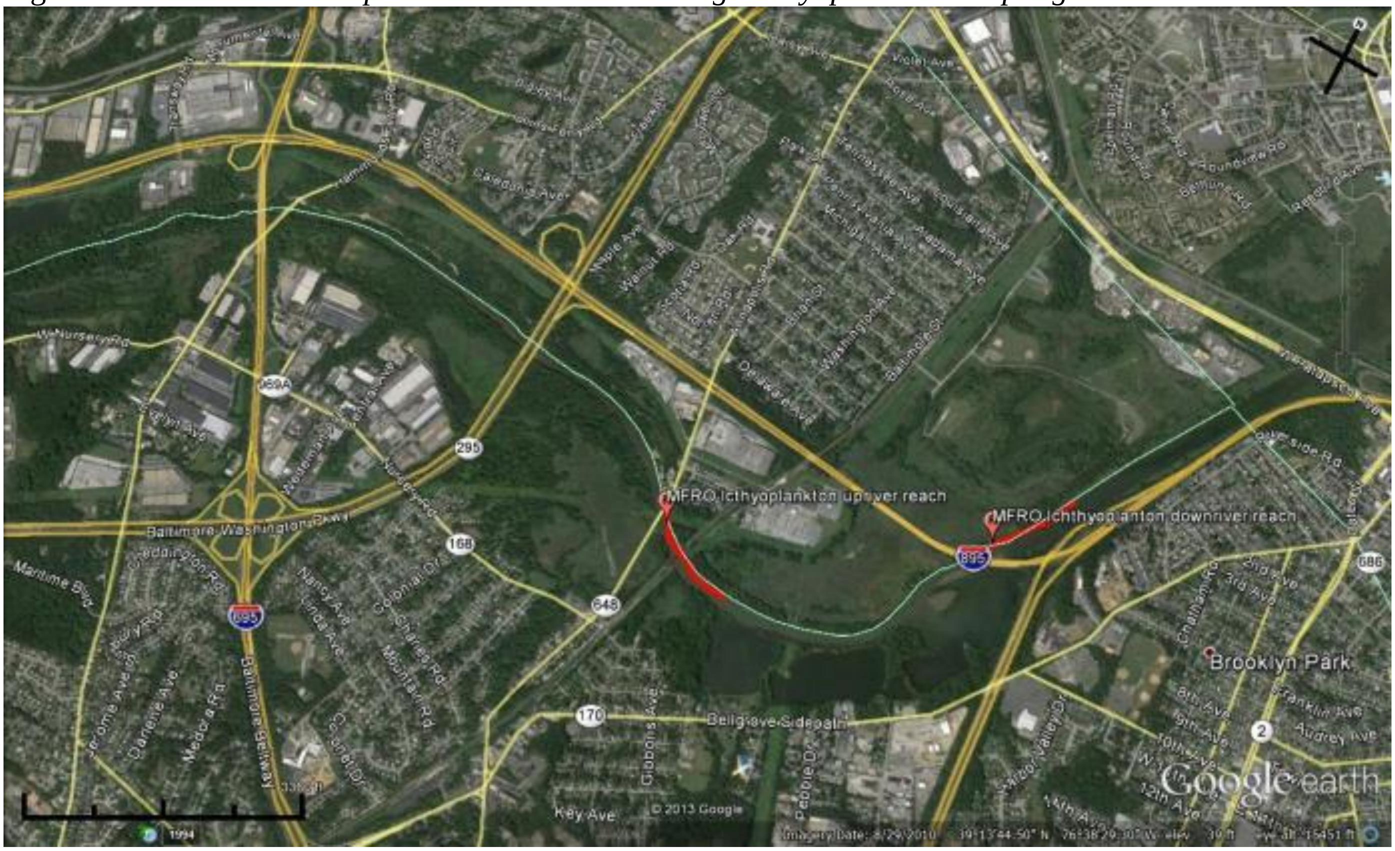


Figure 4. *2013 MFRO Patapsco River shad and herring ichthyoplankton sampling reaches.*



(µmho/cm), salinity (ppt), and dissolved oxygen (mg/L) were recorded at each site using a hand-held YSI model 85 meter (Yellow Springs, Ohio USA). All data were recorded on standard field data forms.

LAB ANALYSIS (LARVAL ICHTHYOPLANKTON NET)

Ichthyoplankton samples were sorted in the laboratory by MFRO personnel. All samples were rinsed with water to remove formalin and placed into a white sorting pan. Samples were sorted systematically (from one end of the pan to the other) under a 10x bench magnifier. All eggs and/or larvae were removed and retained in a small vial with a label (site and date), and fixed with 70% Isopropanol for later identification and/or counting under a microscope. Each sample was then systematically sorted a second time for quality assurance (QA). Any additional eggs/larvae found were removed and placed in a small labeled (site, date, and QA) vial and fixed with 70% Isopropanol for verification. All larvae found during sorting (both original and QA vials) were enumerated and identified as Alewife, Blueback Herring, Hickory Shad, or American Shad. The number of other species, and number of unknown or damaged species, was also recorded. Number of eggs was recorded, but no attempt was made at identifying to species.

Larval catch per unit effort (CPUE) was calculated for all target species as the geometric mean (GM) per tow haul. There were a large number of zeroes in the dataset, so a value of 1 was added to all values in order to calculate the GM. One was then subtracted from the resulting GM for back-transformation. Only back-transformed CPUE values are reported in the results section.

FIELD SAMPLING (JUVENILE SEINE)

The Patapsco River was sampled for juvenile Blueback Herring, Alewife, American Shad and Hickory Shad using fry and juvenile beach seines. Fourteen sites were initially chosen in 2013, but four of the non-tidal upriver sites were discontinued early in the study because no target species were encountered. The nine remaining sites were sampled in 2013, and an additional tenth site was added in 2014. The ten 2014 sampling sites are shown in Figure 5. Sampling was done weekly, beginning June 4, 2014 and ending on September 10, 2014. During the June 4 through June 11 period a fry seine was used, measuring 15.2 meters long, 2.4 meters deep, with 1.6 mm stretch mess. From June 19 through September 10 a beach seine was used, measuring 30.5 meters long, 1.24 meters deep, with 6.4 mm stretch mesh. Both types of seines were deployed by hand, starting at the shoreline and wading perpendicular to the shoreline out into the river, and then arcing back to that shoreline. Juvenile shad and herring were picked from the seine collection, identified to species, placed in plastic bags, labeled, and stored on ice. All other species were identified, enumerated and recorded, then returned to the river. Upon return to the lab, the retained samples were frozen. Only one juvenile Hickory Shad was encountered during the 2014 sampling. CPUE was calculated independently for each target species by calculating the geometric mean of catch data for each seine haul for each site. Zero catches were dealt with the same way as zero catches for ichthyoplankton sampling.

OTC mark presence/absence was determined by MFRO personnel using DNR's Matapeake Lab facility and equipment. Samples were first thawed and measured (fork length [FL] and total length [TL] in mm). Sagittal otoliths were removed by dissection, and mounted on 76.2 mm x 25.4 mm glass slides with Crystalbond 509 (Aremco Products, Ossining, NY). Mounted otoliths were lightly ground on 600 grit silicon carbide wet sandpaper and viewed under epi-fluorescent light at 400X magnification at 50-100 watts with a Zeiss Axioscope 20 microscope. Presence and location (day) of OTC mark epi-fluorescence was recorded. Epi-fluorescence is a technique in which transmitted light in the wavelength of 490-515 nm is allowed to strike the specimen. The specimen then absorbs this light energy and reflects light of a longer wavelength back through the microscope objective.

Figure 5. *2014 MFRO Patapsco River juvenile shad and river herring seining locations.*

Mortality and Abundance Estimates

In addition to providing future brood fish, juvenile stocking is valuable as a pre-migratory stock assessment tool through utilization of multiple mark-recapture techniques (Richardson et al., 2011). This also helps evaluate the efficacy of stocking different life stages and the eventual impact to the returning adult population. Calculation of stocked fish survival, in conjunction with juvenile and adult return data enables cost-benefit analysis of larval vs. juvenile stocking.

There are several assumptions made when using these types of estimates as described by Ricker (1975).

- The marked fish suffer the same natural mortality as the unmarked fish.
- The marked fish are as vulnerable to the fishing being carried on as are the unmarked one.
- The marked fish do not lose their mark.
- The marked fish become randomly mixed with the unmarked; or the distribution of fishing effort (in subsequent sampling) is proportional to the number of fish present in different parts of the body of water.
- All marks are recognized and reported on recovery.
- There is only a negligible amount of recruitment to the catchable population during the time recoveries are being made.

Estimates of juvenile shad and herring abundance, mortality, and survival was derived from the following:

Larval survival to juvenile stocking is calculated by Ricker (1975):

$$S_1 = (R_{12})\, M_2 / (M_1)\, R_{22}$$

$$\text{Variance } S_1 = S_1^2 \{(1/R_{12}) + (1/R_{22}) - (1/M_1) - (1/M_2)\}$$

where M_1 is the number of fish marked at the start of the first interval (larval stocking), M_2 is the number of fish marked at the start of the second interval (early juvenile stocking), R_{12} is recaptures of first interval marked fish in the second interval (after early juvenile stocking), R_{22} is recaptures of early juvenile interval marked fish in the second interval or (after early juvenile stocking), and S_1 is the survival rate of larvae during interval one (from the time of marking larvae in interval one to time of marking early juveniles in interval two).

Instantaneous mortality is derived from survival estimates and is used in conjunction with stocking data to calculate juvenile abundance

$$Z = -\ln S_1 / interval$$

where Z is instantaneous mortality rate and S_1 is survival rate

Abundance of juvenile herring and shad prior to migration is also calculated by Chapman's modification to the Peterson estimate (Ricker 1975):

$$N = \{(C + 1)\ (M + 1)\}\ /\ (R + 1)$$

Where N is the population estimate, M is the number of marked fish stocked, C is the number of fish examined for tags (total captures) and R is the number of marked fish that are recaptured.

From Ricker (1975): Calculation of 95% confidence limits based on sampling error using the number of recaptures in conjunction with Poisson distribution approximation.

Chapman's modification (1951):

$$N^* = \{(C + 1)\ (M + 1)\}\ /\ (R_1 + 1)$$

Where R_1 is from Pearson's formula to calculate upper and lower limits:

$$R_1 = R + 1.92 \pm 1.960\sqrt{R + 1.0}$$

The value (in larvae of stocking early juveniles can be evaluated by calculation (Richardson et al., 2007):

$$LV = \{\ (J_c/J_s)\ /\ (L_c/L_s)\ \}\ (J_s)$$

where LV is the larval value of early juveniles stocked, J_c is the number of early juveniles collected, J_s is the number of early juveniles stocked, L_c is the number of larvae collected as juveniles, and L_s is the number of larvae stocked.

Sub-project 2 Measures of Success

1. Confirmed survival of stocked fish.
2. Calculate CPUE for each species and life stage sampled.
3. Identify the ratio of hatchery fish to wild fish for each species and life stage sampled. This will indicate current spawning success in the target tributary.
4. Calculate larval survival and juvenile abundance of herring and shad species.
5. Identify proportional origin of fish captured by species for each life stage. Origin will be designated as larval-stocked, juvenile-stocked, or wild. This will indicate the impact of stocking each life stage.
6. Early success will be indicated by a large proportion of hatchery-origin juveniles present on the spawning grounds.
7. Juvenile assessment in the third project year should indicate the increasing contribution of wild herring, and possibly Hickory Shad, produced from returning hatchery-origin adults.
8. Comparison of Patapsco River findings to the early years of previous successful restoration activities in the Patuxent River will indicate the impact of the stocking effort.

9. Cost-benefit analysis will indicate the most efficient stocking strategy for Patapsco River mitigation efforts.

Results and Discussion

ICHTHYOPLANKTON

Ichthyoplankton was sampled at four locations beginning April 4, 2014 and continuing through May 29, 2014. During this time frame 28 sampling events occurred encompassing the four locations. Table 3 shows upriver and downriver ichthyoplankton captures.

Table 3. *2014 Patapsco River downriver (MFRO) and upriver (MBSS) ichthyoplankton captures.*

Species	Downriver	Upriver
Alewife	11	0
Blueback Herring	28	15
Hickory Shad	0	0
American Shad	0	0
Non-target species	287	13
Unknown species	9	1
Unidentified eggs	303	2202

Considering targeted and non-targeted species, 11 larval Alewife herring, 43 larval Blueback Herring and 300 larval non-alosine species were caught in 2014. There were no larval American Shad or Hickory Shad caught. The geometric means per ichthyoplankton tow were 0.19 for Alewife and 0.46 for Blueback Herring. The catches for Alewife and Blueback Herring increased from 2013 geometric means of 0.14 for both species. However, catches of larval American and Hickory Shad decreased in 2014 (geometric means of 0.02 and 0.08 in 2013, respectively).

Interestingly, most of the ichthyoplankton biomass (with the exception of eggs) encountered occurred in the lower tidal fresh portion of the river: 92% of all larval fish, and 72% of all larval alosa were caught below Route 648. This is the same pattern that was observed in 2013 (95% of all larval fish and 84% of larval alosa). With Bloede Dam being a fish blockage to upstream areas in the Piedmont, this may suggest the lower tidal portion of the river provides better habitat for larval fish species at present. Much of the river between the dam and the Route 648 crossing has been impacted by sediment. Until Bloede Dam removal occurs, presumably in 2016, stocking the lower portion of the river in the vicinity of Route 648 should continue to be favored.

JUVENILE SEINE SURVEY

Weekly juvenile herring and shad surveys were conducted at ten sites on the Patapsco River (Fig. 5) using fry and beach seines between June 4, 2014 and September 10, 2014. By individual site 126 sampling events occurred.

Targeted species captured during seining included: 114 American Shad, 659 Blueback Herring, 21 Alewife, and 1 Hickory Shad (Table 4). In total, 42 species were collected, including 4,148 young of year (YOY) fish and 4,375 older fish. Other anadromous or semi-anadromous YOY captured were: 116 Striped Bass, 856 White Perch, and 154 Yellow Perch (Table 4). Geometric mean catch per seine haul for juvenile Alewife, American Shad, Blueback Herring, and Hickory Shad was 0.05, 0.42, 0.47 and 0.01 respectively. Only one juvenile Hickory Shad was encountered during the seine survey, and it was a wild fish. For all other target species, both wild and stocked fish were caught (Table 5). Table 6 lists the seine catch for marked and unmarked juveniles by sampling location. At least one juvenile target species was captured at each site. The highest catches of juvenile target species tended to occur in the intermediate sites (i.e. not at the most upstream or downstream sites), centered around Fisherman and Goose Point (Figure. 5).

Table 4. *2014 Patapsco River juvenile seining catch.*

Species	Young of Year	Age 1+
Alewife	21	
American Eel		5
American Shad	114	
Atlantic Menhaden	81	
Atlantic Needlefish	1	
Atlantic Silverside	109	832
Banded Killifish	23	616
Bay Anchovy	1	9
Black Crappie		1
Blacknose Dace	4	1
Blueback Herring	659	
Bluefish	9	1
Bluegill	24	48
Chain Pickerel	2	2
Channel Catfish	2	
Common Carp	1	4
Eastern Mosquitofish		5
Gizzard Shad	1063	193
Golden Shiner		1
Goldfish	2	
Hickory Shad	1	
Hogchoker	1	
Inland Silverside	18	592
Largemouth Bass	67	12
Mummichog	12	257
Naked Goby		1
Pumpkinseed	13	152
Quillback	262	53
Redbreast Sunfish	8	11
Rock Bass	1	
Satinfin Shiner		11
Sheepshead Minnow	1	
Smallmouth Bass	16	
Spotfin Shiner		72
Spottail Shiner	**57**	910
Striped Bass	116	1
Striped Killifish	15	307
Swallowtail Shiner		117
Tessellated Darter	159	65
White Perch	856	70
White Sucker	275	17
Yellow Perch	154	9
TOTAL	**4,148**	**4,375**

Table 5. *2014 Patapsco River juvenile seine catch for marked and unmarked shad and herring species. NS denotes no sample, where a targeted species was captured, but the otolith mark (OTC) was unreadable.*

Species	NS	Larval Mark Stock	Juvenile Mark Stock	Wild
Alewife	--	2	13	6
American Shad	3	40	65	3
Blueback Herring	4	12	0	220
Hickory Shad	--	--	--	1

Table 6. *2014 Patapsco River juvenile seine catch for marked and unmarked shad and herring species by sampling location. NS denotes no sample, where a targeted species was captured but the otolith mark (OTC) was unreadable. Not depicted is one juvenile Hickory Shad (no mark), which was captured at the Boat Ramp site.*

Sampling Location	Alewife				American Shad				Blueback Herring			
	Larval Mark	Juvenile Mark	No Mark	NS	Larval Mark	Juvenile Mark	No Mark	NS	Larval Mark	Juvenile Mark	No Mark	NS
Back Island	--	--	--	--	12	23	--	--	--	--	2	--
Boat Ramp	--	1	1	--	16	21	1	1	1	--	23	--
Borrow Pit	1	1	--	--	1	2	--	--	--	--	16	--
Fisherman Point	--	--	2	--	2	5	1	1	6	--	83	1
Goose Point	--	--	1	--	3	3	1	--	5	--	84	2
Harbor	--	--	--	--	--	--	--	--	--	--	1	--
I895 Bridge	--	--	1	--	5	8	--	1	--	--	1	--
Landfill	--	2	1	--	1	1	--	--	--	--	4	--
Light Rail	--	--	--	--	--	--	--	--	--	--	6	--
River Mouth	1	9	--	--	--	1	--	--	--	--	--	--

ABUNDANCE AND MORTALITY

Alewife

Survival of larval and juvenile stocked Alewives was confirmed by the capture of stocked fish from both life stages. Of the 21 juvenile Alewife otoliths successfully examined, 2 were larval stocked fish, 13 were juvenile stocked fish, and the remaining 6 were wild fish (Table 5). In 2013 no larval or juvenile stocked fish were captured, which suggests survival of hatchery fish increased in 2014. Larval survival to juvenile stocking (S_1) was 0.02 (σ^2=0.0003) and instantaneous mortality (Z) was 0.11. The total juvenile Alewife population in the Patapsco River is estimated to be 1,093,126 (95%CI: 706,382-1,926,214). The estimated abundance of wild juvenile Alewives is 312,322 (95% CI: 201,823-550,347). . Population estimates from 2014 cannot be compared to 2013 because no hatchery released fish were captured in 2013, so 2013 estimates could not be calculated. While survival of stocked fish appeared to increase in 2014, increasing survival of both larval and juvenile stocked Alewives should continue to be a priority in future stocking years. The calculated larval value of stocking 95,000 early juvenile Alewives was 4,550,000, or 47.9 larvae for every early juvenile stocked. If this value continues to be high in future project years, increasing the number of early juveniles stocked may be warranted, if resources allow.

American Shad

Survival of larval and juvenile stocked American Shad was confirmed through the seine surveys. Nearly all American Shad (96.9%) caught during seine surveys were hatchery stocked fish (Table 5). This is nearly the same percentage of hatchery fish captured in 2013, when 98.5% of American Shad juveniles captured were hatchery fish. Larval survival to juvenile stocking (S_1) was 0.48 (σ^2=0.009). Instantaneous mortality (Z) was 0.06. These results indicate stocking American Shad was successful, and that survival of larval and juvenile stocked life stages increased from 2013. There continues to be a relatively low contribution of wild fish to the population of juvenile American Shad. The larval value of stocking early juvenile American Shad was 146,250, or 2.09 larvae for every early juvenile stocked. If survival of larval stocked fish remains relatively similar to juvenile stocked fish, then it may be more cost beneficial to release a higher percentage of larval fish, as the cost to produce larvae is less than early juveniles.

The Chapman estimate for total juvenile abundance of American Shad in the Patapsco was 164,529 (95% CI: 137,216-201,061), a 68% increase in abundance from 2013 (N_{2013}=97,880). The wild juvenile abundance is estimated to be 4,570 (95% CI: 3,812-5,585). Based on these estimates, it appears the presence of juvenile American Shad in the Patapsco River is due largely to hatchery stocking efforts. However, the estimated wild juvenile abundance estimate did increase three-fold in 2014, from a 2013 estimate of only 1,461. It also appears that survival of larval stocked American Shad may have increased significantly in 2014, as no larval stocked fish were captured in 2013. The lack of wild American Shad within the juvenile samples is somewhat expected, given that only one mature adult American Shad was captured during adult sampling (see sub-project 3), and no larval American Shad were captured during ichthyoplankton surveys. There was also only one adult American Shad captured in 2013. Continued monitoring for the presence of wild American Shad should be a good indicator for restoration progress within the Patapsco River.

Blueback Herring
Larval stocked Blueback Herring were recaptured during seine surveys, thus confirming their survival (Table 5). However, survival of juvenile stocked Blueback Herring could not be confirmed, as none were captured. Of the 232 juvenile Blueback Herring otoliths examined, 220 were from wild fish (94.8%). The 12 recaptures of hatchery origin fish were all larval stocked fish. The survival rate (S_1) of larvae to juvenile stocking could not be calculated because no juvenile stocked fish were recaptured. One potential reason for no juvenile stocked fish being recaptured was due to low numbers of juvenile stocked fish. In 2014 only 1,500 juvenile Blueback Herring were stocked into the Patapsco River, as opposed to 57,000 stocked juveniles in 2013. No comparison was made between the larval value of stocking early juveniles of 2013 and 2014 because that value for 2014 could not be calculated because no stocked juveniles were recaptured.

The total population of juvenile Blueback Herring in the Patapsco River is estimated to be 12,178,749 (95% CI: 7,543,938-23,102,433). The total wild juvenile abundance for Blueback Herring is estimated to be 11,548,813 (95% CI: 7,153,735-21,907,479). These population estimates may be inaccurate (note wide confidence intervals around estimate), due to a low number of recaptured marked fish, and the large number of marked fish released. Survival may have been poor for marked fish, leading to low recapture rates. Increasing the likelihood of survival for both larval and juvenile-stocked fish should be of high importance. The high percentage of wild caught fish does suggest a strong remnant population within the Patapsco River.

Hickory Shad
Survival of larval or juvenile stocked Hickory Shad could not be confirmed because there were no stocked juvenile Hickory Shad caught during seine surveys. There was only one wild Hickory Shad juvenile caught during seine surveys. This was the first capture of a juvenile Hickory Shad during the project. Future seine survey work will continue to monitor for all target species' presence, including Hickory Shad. It may be difficult to monitor stocking success for Hickory Shad through juvenile seine surveys, because capture of juvenile Hickory Shad is difficult (Richardson et al. 2009). A better indicator of stocking success will likely be the return of hatchery stocked fish as adults, which could be detected during adult spawning surveys (see sub-project 3). For other rivers within Maryland this has proved to be a good measure of stocking success for Hickory Shad (Richardson et al. 2009).

HYDROLOGIC DATA

River flows in the Patapsco River were significantly higher in 2014 than in 2013. Average daily discharge measured at the USGS gauge at Hollofield MD was nearly twice as high in 2014 (423 cubic feet per second (cfs)) than in 2013 (221 cfs). Historic mean flows for the last 57 years at this site are 272 cfs. Several high flow events coincided with the spawning season for shad and river herring. There were three high flow events over 2000 cfs during April and May in 2014. There were no high flow events in 2013 over 1000 cfs during this timeframe. Increased flows during spawning season have been correlated to increased reproduction of anadromous species (Martino 2008). Higher numbers of wild fish captured and increased survival of stocked fish could be due to higher flows increasing the likelihood of spawning success and survival of stocked fish in 2014. Chesapeake Bay-wide seine survey indices for Alewife, American Shad, and Blueback Herring also support the notion that there was increased recruitment for shad and river herring compared to 2012 and 2013 (Durrell and Weedon 2014).

Sub-project 3:
Assess the contribution of hatchery fish to the adult American Shad and Hickory Shad and herring spawning population.

Adult assessment will document current populations of target species and monitor future adult returns of American Shad, Hickory Shad, and river herring. American Shad will not be fully recruited to the spawning population during the funding timeframe due to their later age at maturity. The funding timeframe does not permit robust monitoring or assessment of any adult Alosine populations. Adult sampling will take place in project years two through six.

Materials and Methods

Adult herring and shad surveys were conducted beginning March 20, 2014, and continued through May 29, 2014. Sampling occurred once a week, and was conducted by MBSS using a Smith-Root (Vancouver, WA) electrofishing boat in the upper, non-tidal portion of the study area (Figure 6), and by MFRO using a Smith-Root electrofishing boat in the lower, tidal portion of the study area (Figure 7). The upper section of the river was sampled at three river reaches, and the lower section was sampled at two river reaches, for approximately 1,000 to 1,500 seconds. Sampling occurred within the general vicinity of larval ichthyoplankton and juvenile collections. River reaches were sampled upstream to downstream, with constant voltage being applied for the entire run. Total shock time was recorded. All target species were externally examined for sex, measured for fork length (FL) and total length (TL), and enumerated for catch per unit effort (CPUE). Catch per unit effort was measured as total fish caught (per species) divided by shock seconds. Data were transformed to number of fish caught per hour. Analysis of variance (ANOVA) was done to examine any potential difference in FL between males and females.

Scale samples were taken for age analysis, and were aged using methods described by Cating (1953). Scales were independently examined for ages by two readers. If there was no consensus between the two readers, a third reader was used to examine scale age. If no consensus could be reached between all readers, or if scales were unreadable, they were excluded from analysis. In order to determine adult mortality of collected species, a catch curve analysis was done. Catch curve analysis was done by calculating the slope of a linear regression with natural log transformed total catch at age as the independent variable and age as the dependent variable. The slope of the line is equal to total instantaneous mortality for adults (Z). Catch curve analysis was done on fish aged 4 thru 6, because catch at age progressively declined after 4 years of age. Male and female catches were combined to calculate total catch for each species. Scales were also examined for spawning checks. The number of spawning checks was recorded for each scale examined. The first and second years of monitoring did not involve otolith extraction, as no hatchery origin adult fish would be expected. Subsequent project years (4-6) will involve otolith extraction, and assessment under epifluorescent light to identify hatchery-origin fish.

Sub-project 3 Measures of Success

1. Collect samples of adult shad and herring species.
2. Identify current presence of wild target species adults
3. Utilize length-frequency analysis to assess adult population structure.
4. Utilize age analysis to assess adult population structure.
5. Analyze proportional contribution of hatchery and wild origin adults.
6. Presence of hatchery adults indicates survival and fidelity. Absence does not necessarily indicate failure considering the truncated timeframe.

Figure 6. *2014 MBSS Patapsco River adult shad and herring electrofishing reaches.*

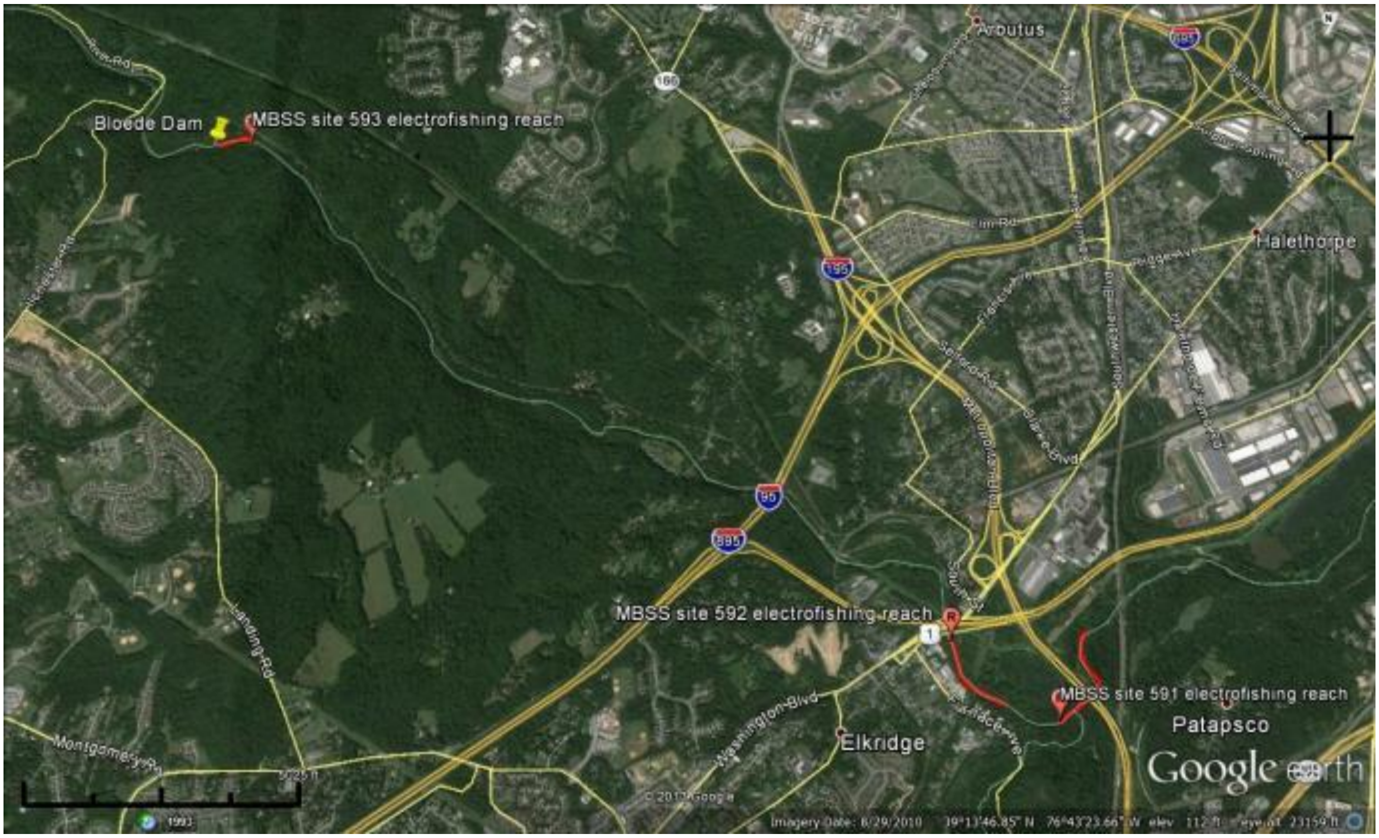
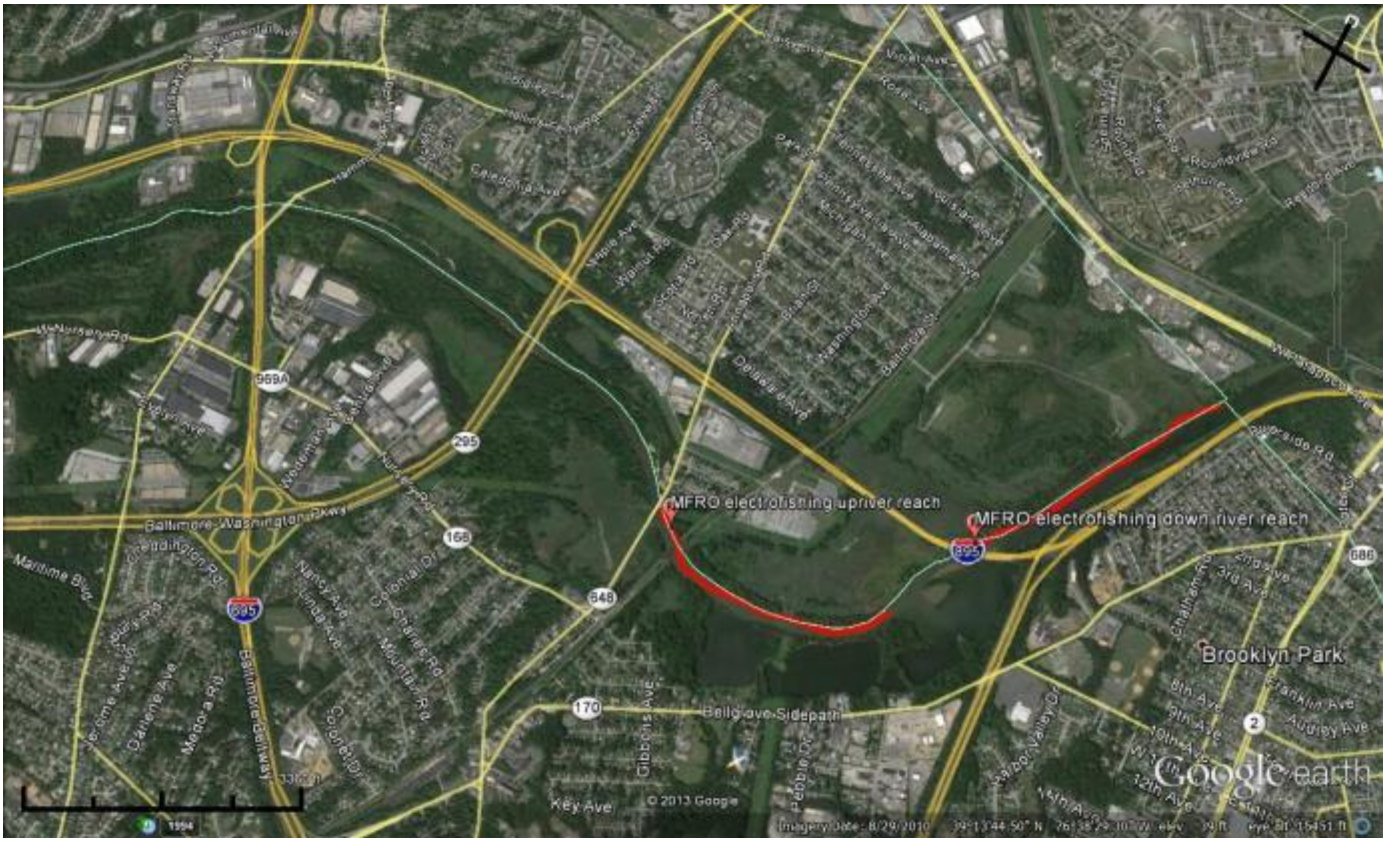


Figure 7. *2014 MFRO Patapsco River adult shad and herring electrofishing reaches.*



Results and Discussion

Adult shad and herring were sampled by electrofishing at five locations beginning in March 20, 2014 and continuing through May 29, 2014. During this time frame 43 sampling events occurred encompassing the five locations. A total of 109 Alewife Herring, 135 Blueback Herring, 21 Hickory Shad, and 1 American Shad were caught. Table 7 shows number of individuals caught by species and sampling location. An additional 35 adult Blueback Herring were captured via castnet by MBSS at site MBSS 593. Only one American Shad was caught, and that individual was encountered at an upriver MFRO sampling location. The downriver reach sampled by MFRO did not produce a high number of target fish. MBSS captures of targeted fish in the upper portion of the study area totaled 183 individuals. This is up slightly from the 2013 catch of 160 individual target fish. MFRO captures of targeted fish in the lower portion of the study area totaled 83 individuals (Table 7). This is more than twice the amount of target fish captured by MFRO in 2013 in the lower portion of the study area. This is largely due to the increase in catches of both Alewife and Blueback Herring.

The upper (MBSS) portion of the adult shad and herring sampling area may have allowed for better capture rates of targeted species. The shallow depth and high water clarity may have increased capture efficiency as compared to the lower (MFRO) portion of the study area which is deeper and turbid. Additionally, the blocking effect of Bloede Dam most likely concentrated fish in the upper reach. Regarding the low catch of American Shad, Maryland DNR experience has shown that this species can more easily avoid electrofishing capture than the closely related Hickory Shad. The result is that American Shad adults are probably not fully represented in spawning ground sampling. The larval and juvenile survival, mortality and abundance estimates presented in sub-project two of this report can serve as an important indicator of restoration progress.

Catch rates for most species were generally similar, with the exception of American Shad (Fig. 8). Catch-per-unit effort for all species ranged from 0.0-124.4 fish per electrofishing hour. The highest catch rates occurred for Blueback Herring collected in mid-May. Alewife and Hickory Shad were encountered during mid- to late April, with Blueback Herring not encountered until late April. This follows expected patterns due to the spawning behavior of each species, with Alewives and Hickory Shad spawning prior to Blueback Herring. Species were encountered relatively later in the year, compared to 2013. Generally, catches peaked about 1-2 weeks later in 2014 than 2013. This was likely due to a colder than normal winter and early spring.

Both males and females were encountered for all species except for American Shad (Table 8). The single American Shad captured was a female with a FL of 405 mm. It was 6 years old and a repeat spawner. Female to male ratio varied for all species (with the exception of American Shad). Males dominated the catches of Alewives, with nearly 3 males for every female. Hickory Shad male to female ratio was 1.85:1, and Blueback Herring male to female ratio was 1.73:1. These rates were all higher than in 2013, when ratios for all species were approximately 1.5:1. Adult ages ranged from 3 to 6 for all captured river herring and shad (Fig. 9; Table 9). For Alewife and Blueback Herring, the majority of fish were age 3. In 2013, the dominant age class for Alewife and Blueback Herring was age 4. The dominant age class for Hickory Shad was age 4, the same as in 2013. No age 3 fish of any species was a repeat spawner (Table 9). This is an expected result, as age 3 should be the age when most fish become sexually mature and make their first spawning run. As fish became older, there were more repeat spawners. However, in 2014 there was a significant reduction from 2013 in the overall percentage of repeat spawners for each species. In part, this is likely due to the dominant age class being age-3 fish for river herring spp., which should be spawning for the first time. The only increase in repeat spawners from 2013 was for female Blueback Herring, which increased from 0.0% in 2013 to 15.0% in 2014. In the future, continued monitoring of the number of repeat spawners of Blueback Herring will be important to measure successful restoration of this species. In 2015, it is possible that fish stocked in 2012 will be returning to the river to spawn for the first time. Analysis of otoliths from adults will be done in 2015 to determine contribution of stocked fish to the adult population.

Length range for all species collected is shown in Figure 10. Average length at age for each species, listed by sex is shown in Table 10. Females were generally larger than males for all species. There were significant differences between male and female lengths for Alewife and Blueback Herring, but not for Hickory Shad (Alewife ANOVA, $F_{1,81}=19.39, p<0.001$; Blueback Herring ANOVA, $F_{1,106}=37.47, p<0.001$; Hickory Shad ANOVA, $F_{1,18}=1.75, p=0.20$). All adult fish captured in 2014 were aged; therefore a length at age key was not developed for fish this year. In future years, assuming catches increase, a length at age key will be developed to help determine ages for fish that do not undergo scale analysis. However, for all species there was a high amount of overlap among lengths at age (Table 10), which suggests length may not be a good surrogate for age.

Total instantaneous mortality rates (Z) for adults were 1.98 for Alewife and 1.12 for Blueback Herring. Mortality could not be calculated for Hickory Shad because only two year classes were captured. The corresponding survivorship rates for Alewife and Blueback Herring are 0.14 and 0.33, respectively. Alewife mortality increased slightly from 2013 (Z=1.72). Mortality for Blueback Herring decreased approximately 40% from 2013 (Z=1.88). Mortality estimates for both species are generally in agreement with previous river herring and shad studies conducted along the Atlantic Coast (Grist 2005; Armstrong 2008). Mortality rates will continue to be monitored through age analysis in project years 4 thru 6.

Table 7. *2014 Patapsco River adult shad and herring electrofishing catches by sampling location.*

Sampling Location	Alewife	American Shad	Blueback Herring	Hickory Shad
MBSS 591	62	--	40	15
MBSS 592	14	--	29	1
MBSS 593	3	--	18	1
MFRO Downriver	2	--	3	1
MFRO Upriver	28	1	45	3

Table 8. *2014 Patapsco River adult shad and herring electrofishing catches by species and sex.*

Species	Male	Female	Total
Alewife	62	21	83
American Shad	--	1	1
Blueback Herring	69	40	109
Hickory Shad	13	7	20

Table 9. *Number of adult Alewife (A), Blueback Herring (B), and Hickory Shad (C) captured in the Patapsco River in 2014, listed by sex and age. The number of repeat spawners is listed by species, sex, and age. Not depicted is one American Shad, which was a 6 year old female.*

A) Alewife

Age	Male		Female		Total	
	N	Repeat	N	Repeat	N	Repeat
3	42	0	11	0	53	0
4	19	0	10	2	29	2
5	1	1	0	0	1	1
Totals	*62*	*1*	*21*	*2*	*83*	*3*
% Repeats	*1.6*		*9.5*		*3.6*	

B) Blueback Herring

Age	Male		Female		Total	
	N	Repeat	N	Repeat	N	Repeat
3	45	0	21	0	66	0
4	20	3	15	3	35	6
5	3	0	4	3	7	3
Totals	*68*	*3*	*40*	*6*	*108*	*9*
% Repeats	*4.4*		*15.0*		*8.3*	

C) Hickory Shad

Age	Male		Female		Total	
	N	Repeat	N	Repeat	N	Repeat
3	5	0	3	0	8	0
4	8	2	4	0	12	2
5	0	N/A	0	N/A	0	N/A
Totals	*13*	*2*	*7*	*0*	*20*	*2*
% Repeats	*15.4*		*0.0*		*10.0*	

Figure 8. *Electrofishing catch-per-unit effort (CPUE) for all adult river herring and shad species captured on the Patapsco River in 2014. Note: only one American Shad was caught for all trips and occurred on May 15, 2014.*

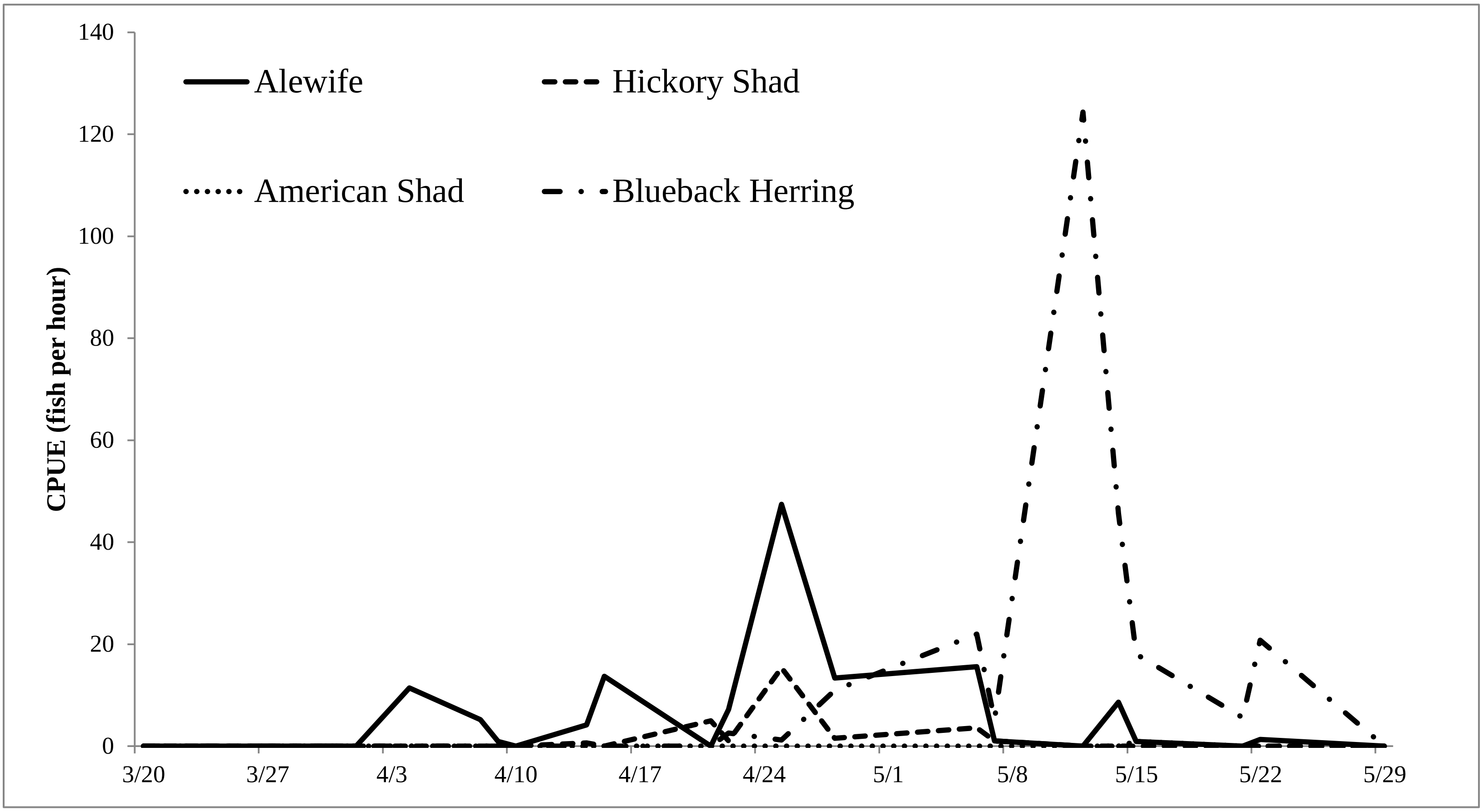


Figure 9. *Catch at age for Alewife, Blueback Herring, and Hickory Shad captured in the Patapsco River in 2014. Not depicted is one American Shad, which was 6 years old.*

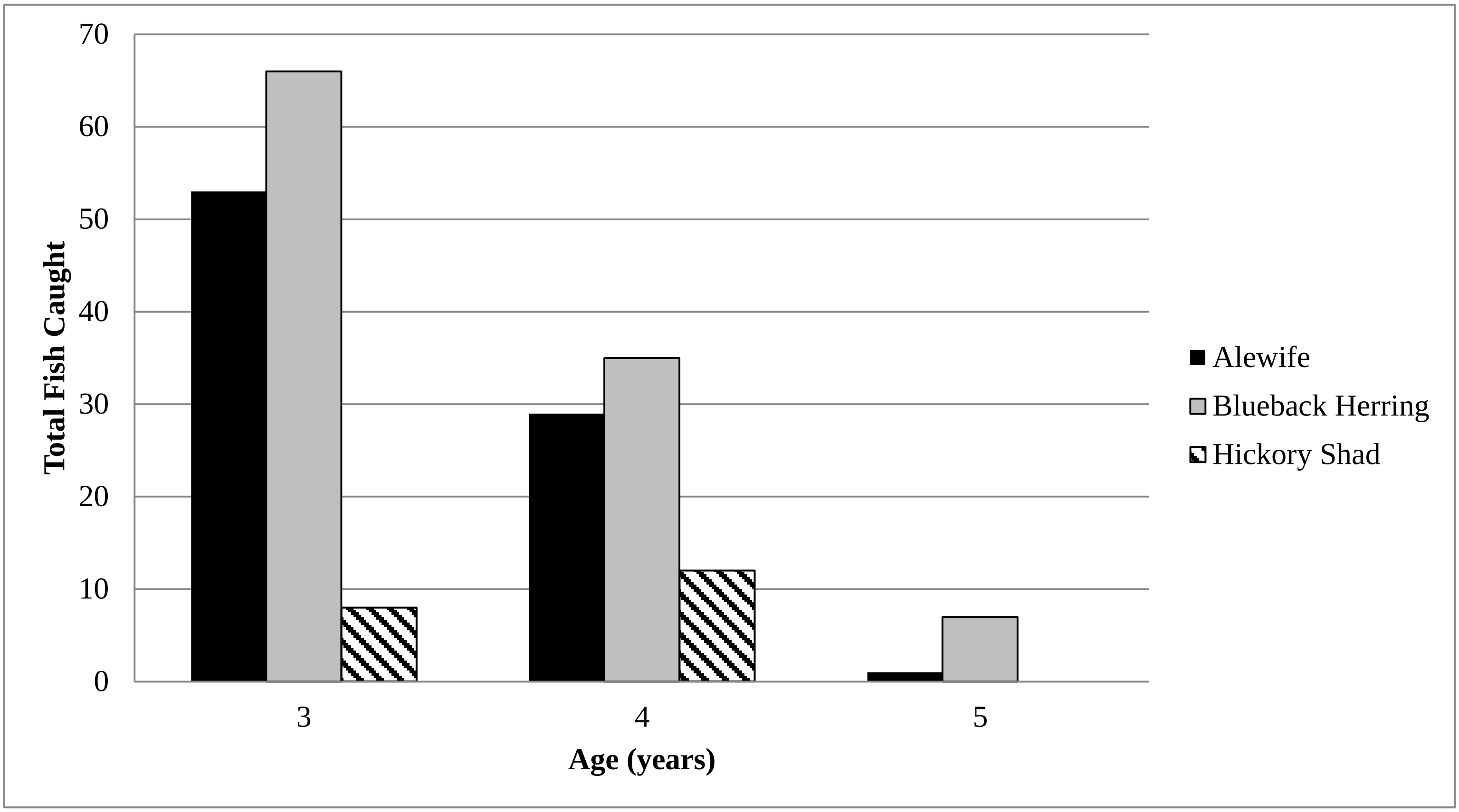


Figure 10. *Length- frequency for adult Alewife (A), Blueback Herring (B), and Hickory Shad (C) captured during electrofishing trips on the Patapsco River in 2014. Note the differently scaled axes for each species.*

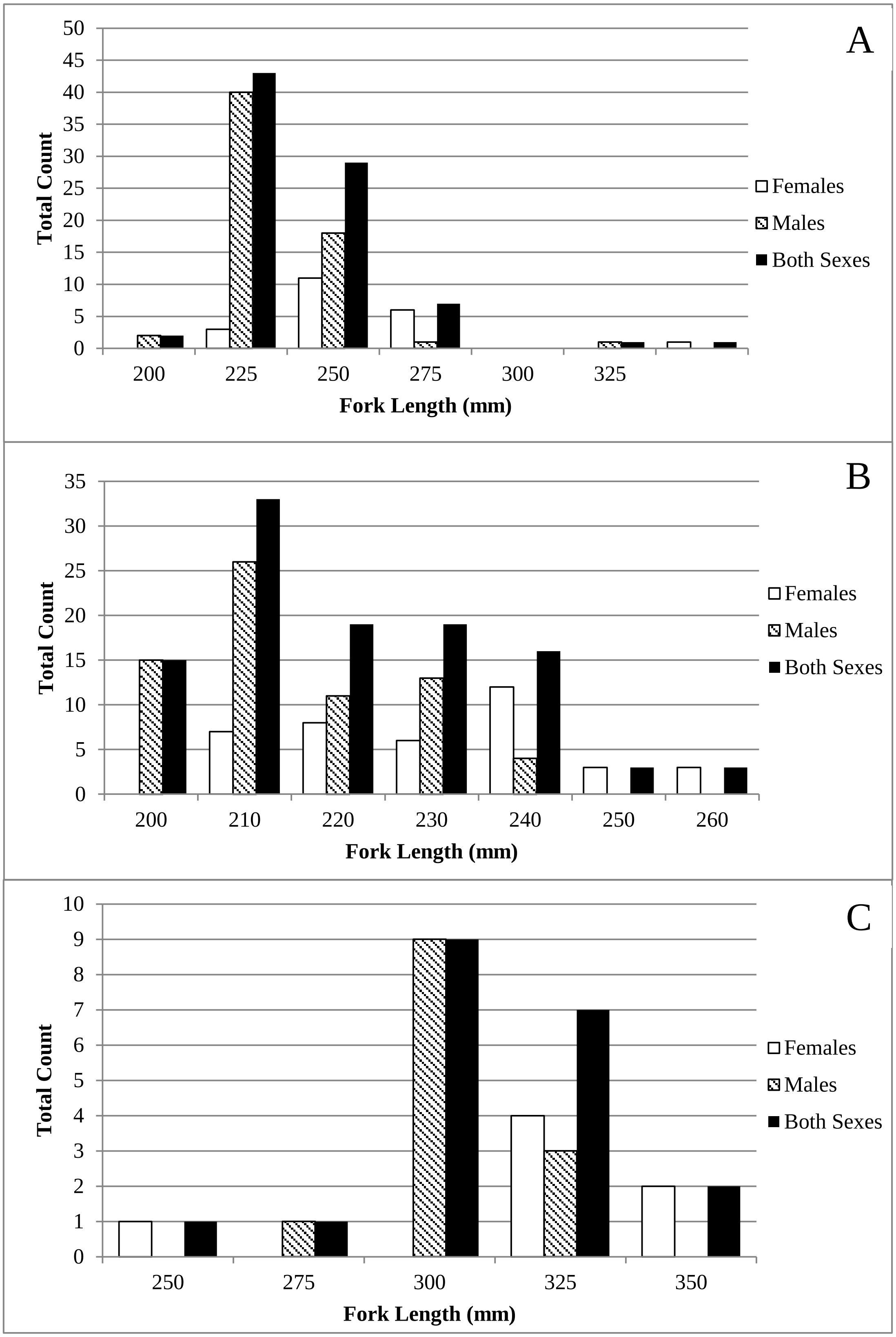


Table 10. *Sex-specific length at age (±SD) for Alewife, Blueback Herring, and Hickory Shad adults collected from the Patapsco River in 2014. Instantaneous natural mortality (Z) is listed for each species in its entirety. Not depicted is one American Shad, which was 6 years old.*

	Alewife		Blueback Herring		Hickory Shad	
Age	Male	Female	Male	Female	Male	Female
3	221 *(20)*	245 *(32)*	204 *(7)*	215 *(12)*	318 *(19)*	307 *(39)*
4	221 *(13)*	244 *(15)*	221 *(11)*	235 *(7)*	313 *(8)*	349 *(17)*
5	226 *(0)*		222 *(4)*	243 *(8)*	N/A	N/A
Z	1.99		1.12		N/A	

Overall 2014 Project Monitoring Conclusions

- While survival of stocked Alewives appeared to increase in 2014, increasing survival of both larval and juvenile stocked Alewives should continue to be a priority for future stocking years. The calculated larval value of stocking 95,000 early juvenile Alewives was 4,550,000, or 47.9 larvae for every early juvenile stocked. If this value continues to be high in future project years, increasing the number of early juveniles stocked may be warranted, if resources allow.

- There continues to be a relatively low contribution of wild fish to the population of juvenile American Shad (nearly all, 96%, caught during seine surveys were hatchery stocked fish). The larval value of stocking early juvenile American Shad was 146,250, or 2.09 larvae for every early juvenile stocked. If survival of larval stocked fish remains relatively similar to juvenile stocked fish, then it may be more cost beneficial to release a higher percentage of larval fish, as the cost to produce larvae is less than early juveniles.

- Population estimates given in the report for Blueback Herring may be inaccurate due to the low number of recaptured marked fish, and the large number of marked fish released. Larval stocked Blueback Herring were recaptured, thus confirming their survival. However no juvenile stocked Blueback Herring were recaptured. Survival may have been poor for marked fish. The high percentage of wild caught fish does suggest a strong remnant population within the Patapsco River.

- Survival of larval or juvenile stocked Hickory Shad could not be confirmed because there were no stocked juvenile Hickory Shad caught during seine surveys. There was only one wild Hickory Shad juvenile caught during seine surveys. This was the first capture of a juvenile Hickory Shad during the project. A better indicator of stocking success will likely be the return of hatchery stocked fish as adults, which could be detected during adult spawning surveys.

- Upper coastal plain, the area between the Route 648 crossing of the Patapsco River and Bloede Dam, appears to be impacted by course grained sediment. Alosid larval and juvenile habitat is lacking.

- Lower tidal fresh portion of the river appears to be functional habitat for larval and juvenile shad and herring species as well as for other anadromous and semi-anadromous species.

- Stocking in the lower portion of the river, in the vicinity of Route 648 and SW Area Park, should continue until such time when Bloede Dam is removed.

- Bloede Dam removal scheduled in 2016 will open the piedmont region to alosid species. That habitat could be of better quality than what is available downstream of the dam in the non-tidal portion of the river.

- Extending stocking and assessment could determine the effects of dam removal on restoring shad and river herring in the upper watershed. Current funding only pays for three years of stocking and five years of assessment. For shad in particular, Maryland DNR restoration work thus far indicates that self –sustaining restoration will likely occur over a period of decades, rather than years. With dam removal not slated until 2016, present funding will not address the benefits of Bloede Dam removal to shad and herring in the upper watershed.

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